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GB 1135449
GB 1084438
GB 1055643
GB 1035509
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(54) **Hydropneumatic self-levelling suspension units of the self-pumping type**

(57) A hydropneumatic self-levelling suspension unit of the self-pumping type is provided with a passage 50 from the working chamber 100 back to the reservoir 134 which opens when the load applied to the vehicle is decreased. If the load is increased and the unit becomes contracted to less than the mean height, liquid is pumped from the reservoir 134 to the working chamber 100 via suction valve 38, a pump chamber in the hollow piston rod, and exhaust valve 40. The unit extends until the piston uncovers the passage 50. There is also a second passage 60 provided in the cylinder wall through which liquid also escapes when the displacement is large, thereby enabling the time required for levelling to be shortened.

FIG.2

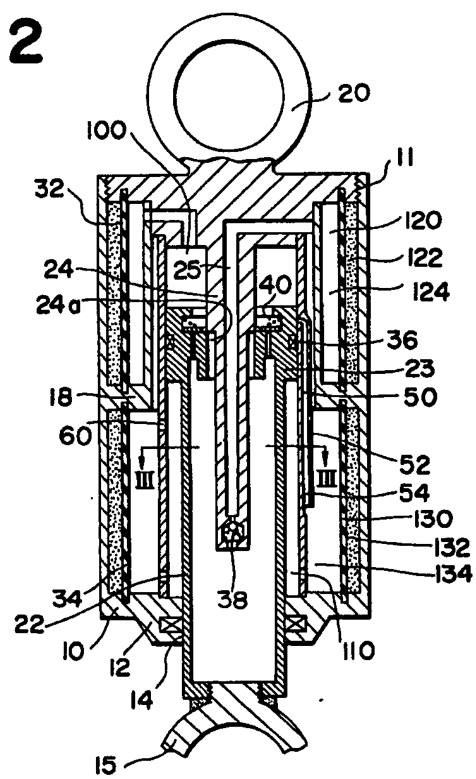

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FIG.1

PRIOR ART

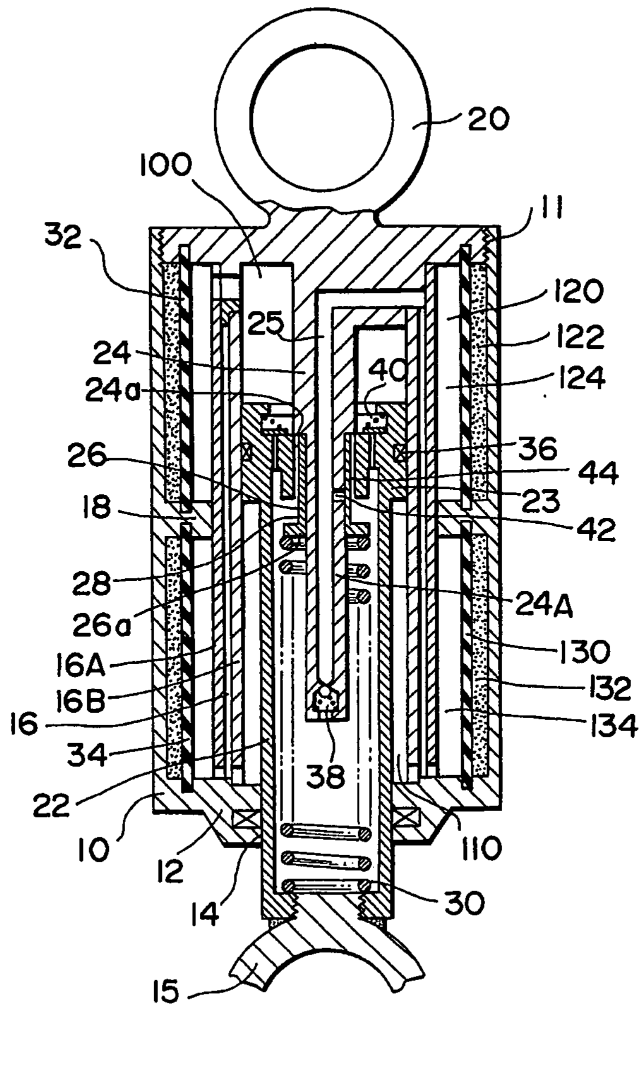

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FIG.2

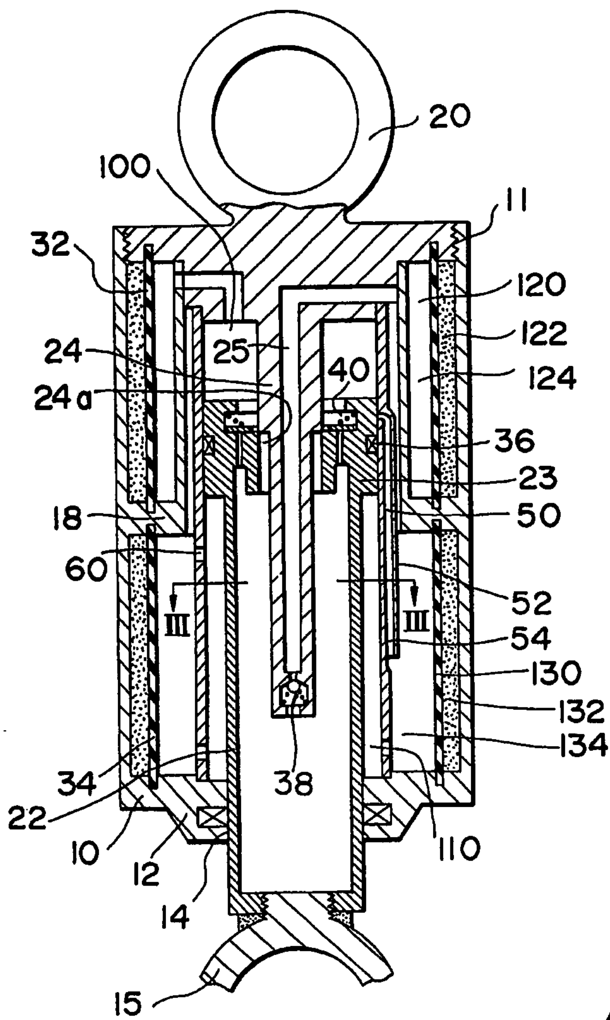


FIG.3

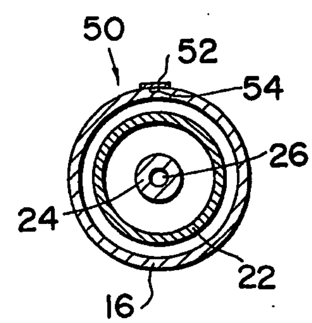


FIG.4

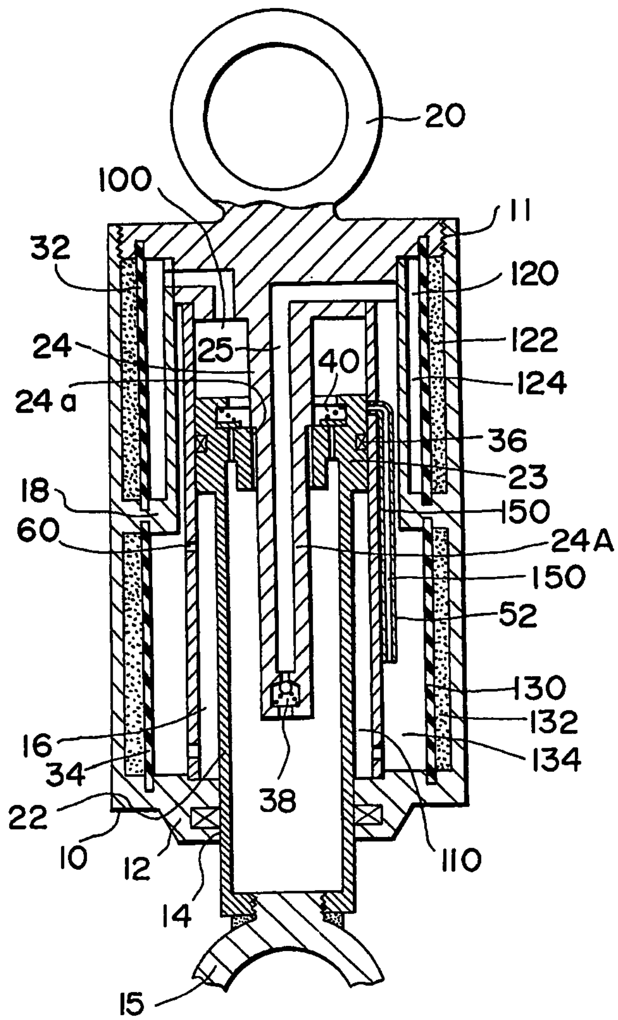
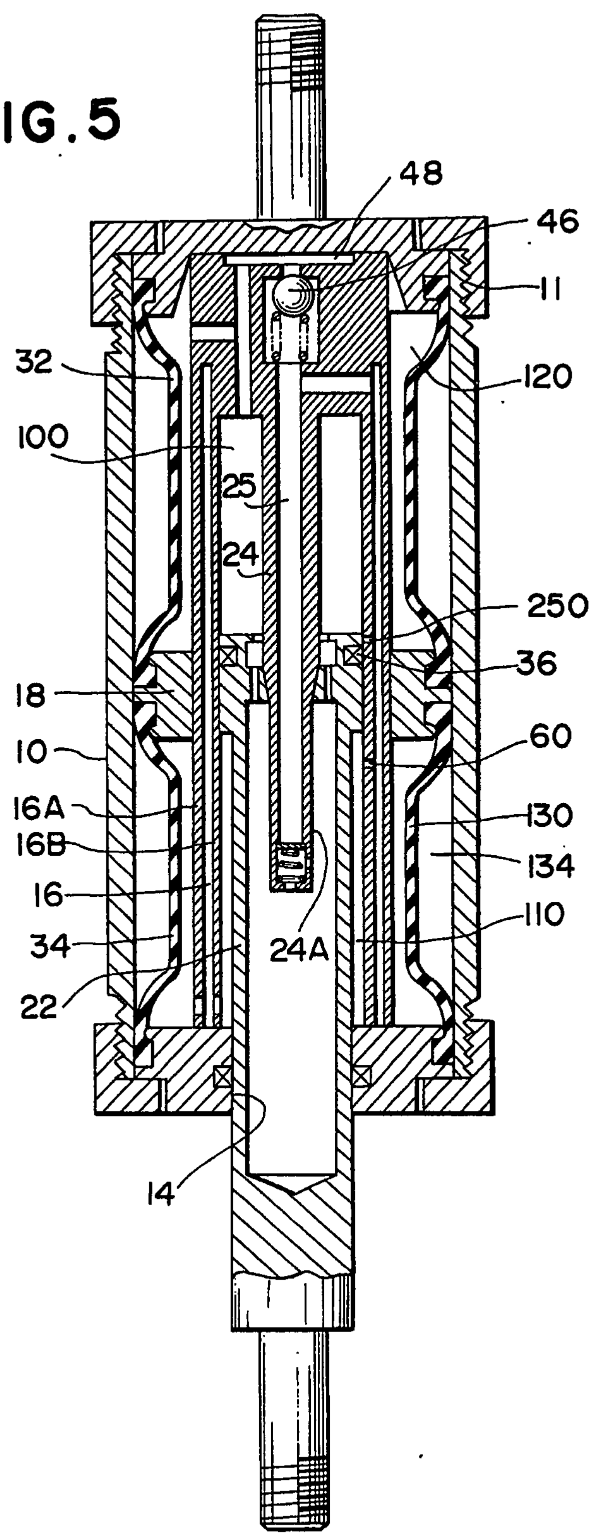

20
100
11
32
120
24
25
122
40
24a
124
36
23
18
150
60
24A
150
52
130
132
16
134
34
38
22
10
12
110
14
15

FIG.5


48
46
11
32
120
100
25
24
250
36
18
10
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16A
130
16B
134
16
110
34
24A
22
14

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FIG.6

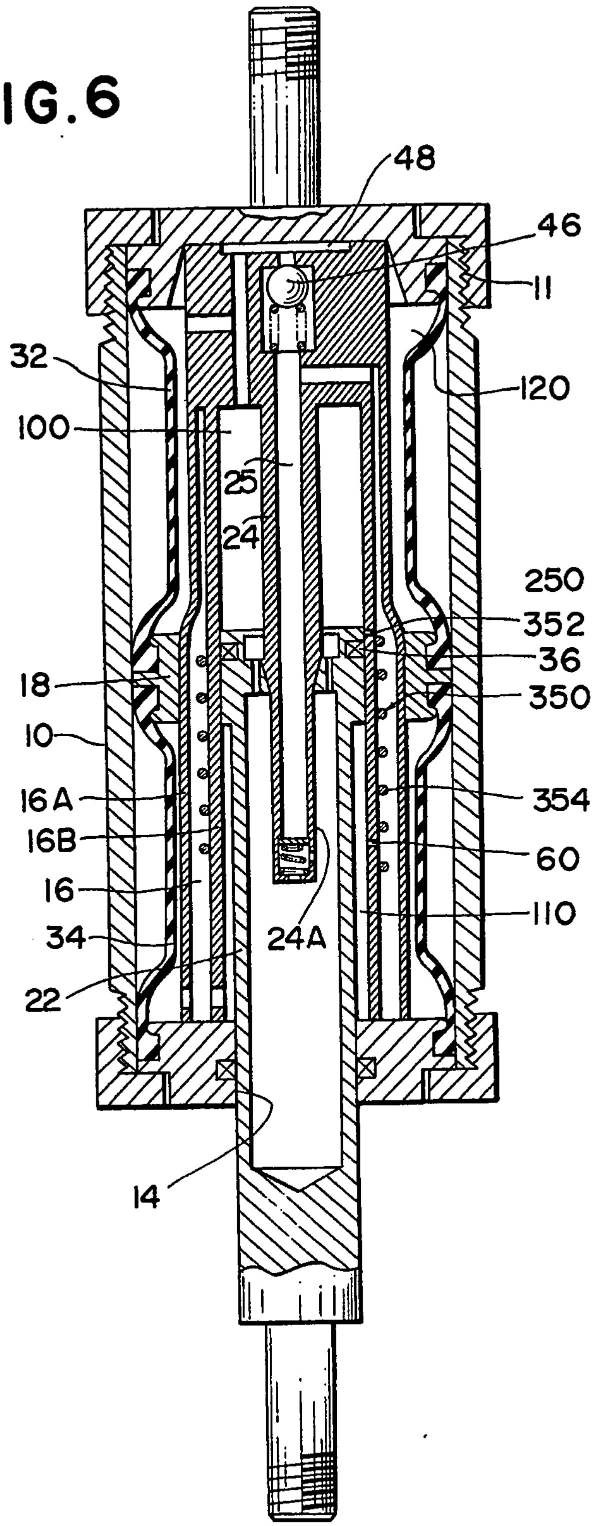


FIG.7

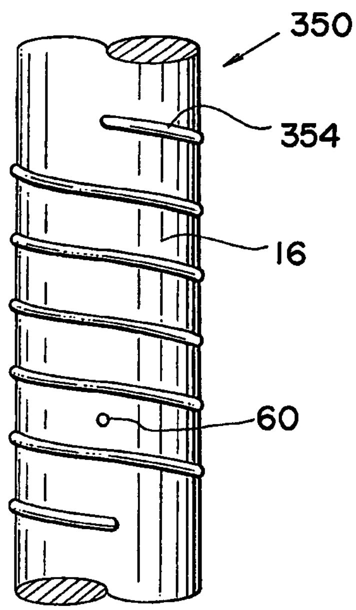


FIG.8

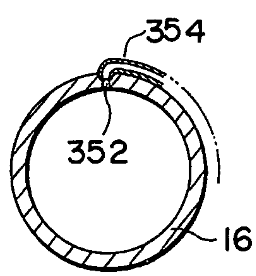
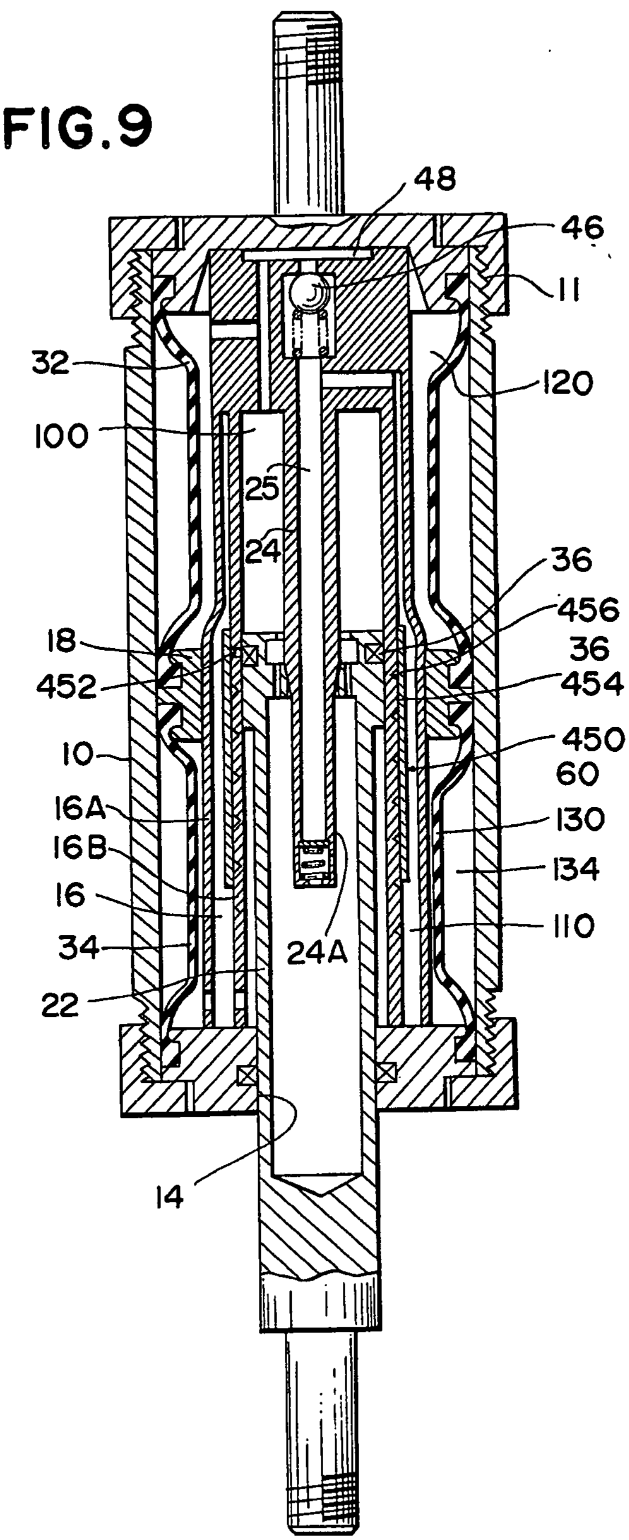


FIG.9


48
46
11
32
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100
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24
36
456
18
36
452
454
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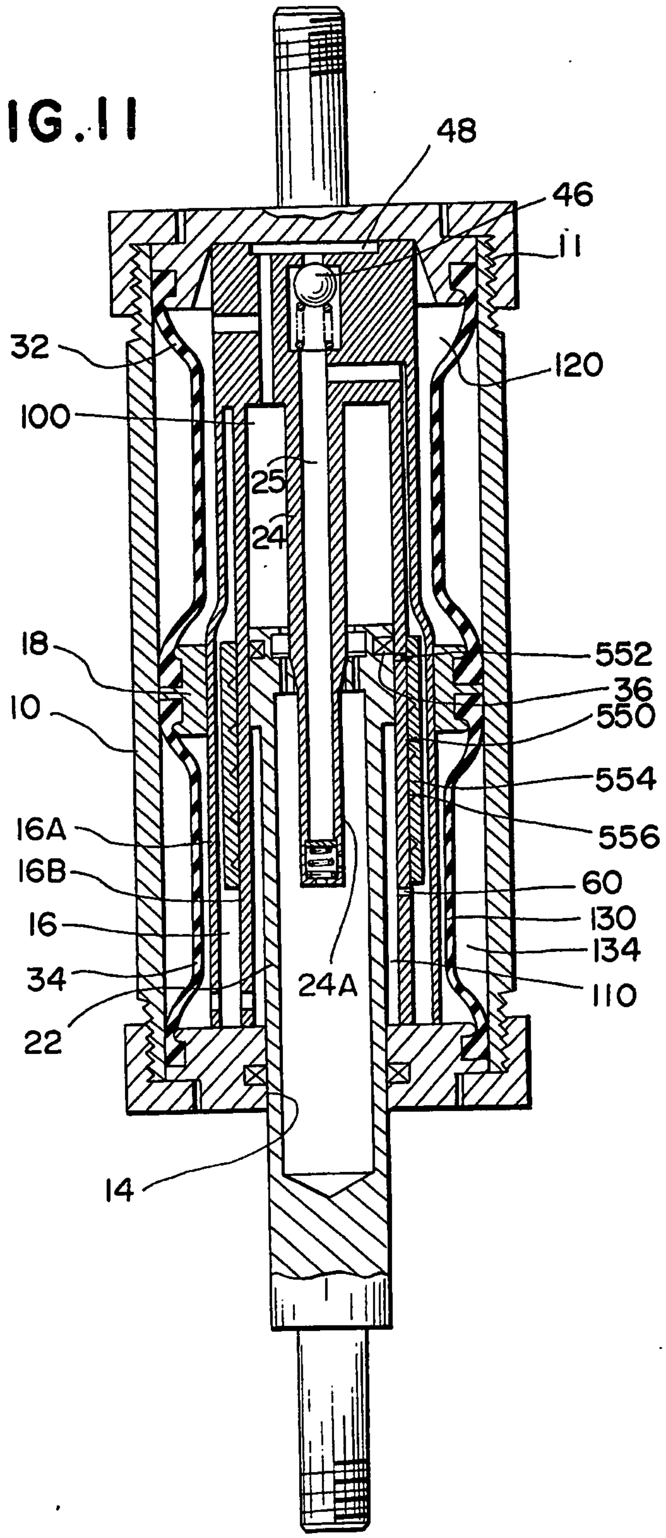
450
60
16A
130
16B
134
16
110
34
24A
22
14

FIG.11


48
46
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120
100
25
24
18
552
36
10
550
554
556
16A
16B
60
130
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134
34
24A
110
22
14

FIG.10

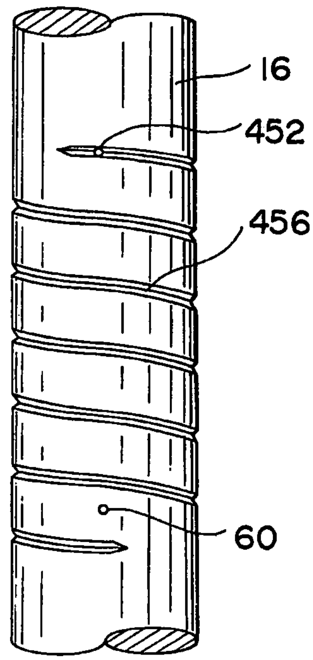


FIG.12

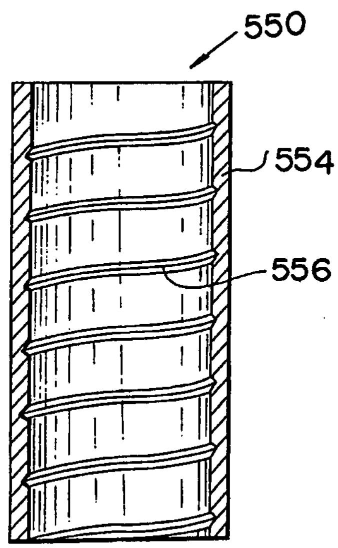


FIG.10

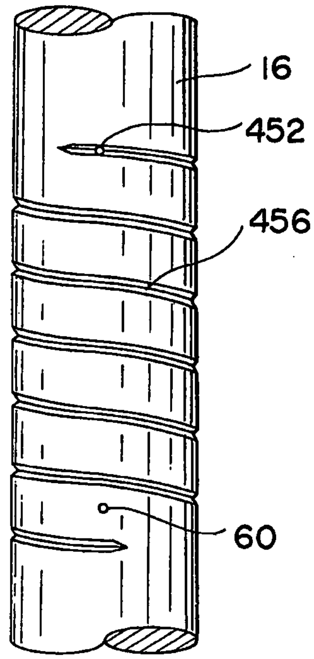
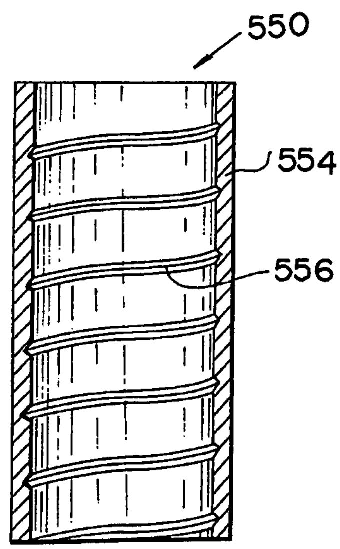


FIG.12



SPECIFICATION

Hydropneumatic suspension for an automotive vehicle

The present invention relates to hydropneumatic suspension for an automotive vehicle, and more particularly to a suspension disposed between a vehicle body and an axle or a wheel shaft for adjusting the vehicle height.

Conventional hydropneumatic suspensions comprise a suspension cylinder having an outer tubular member and an inner tubular member, a piston consisting of a hollow cylindrical member and having a piston head slidably fitted into the inner circumferential surface of the inner tubular member with a liquid-tight relationship, a cap member fitted over the cylinder so as to cover the upper end thereof, and an elongated tubular means, including a liquid passage therein, provided through the piston head, the upper end of which is integrally connected to the cap member while the lower end of which extends to the axial direction of the piston.

The elongated tubular means is provided at the lower end with a suction valve communicating with one end of the liquid passage. Further, an ejecting valve is provided within the piston head.

The inner circumferential surface of the inner tubular member, the upper surface of the piston head, the outer circumferential surface of the elongated tubular means, and the lower surface of the cap member define a first working liquid chamber. The inner circumferential surface of the inner tubular member, the lower surface of the piston head, and the outer circumferential surface of the hollow cylindrical member define a second working liquid chamber.

The space between the outer tubular member and the inner tubular member is partitioned into first and second outer chambers.

The conventional suspension further comprises a first cylindrical diaphragm disposed within the first outer chamber, and a second cylindrical diaphragm disposed within the second outer chamber.

The first diaphragm partitions the first outer chamber into a first gas chamber and a third working liquid chamber. The second diaphragm partitions the second outer chamber into a second gas chamber and a fourth working liquid chamber.

A pumping chamber is defined by the inner surface of the hollow cylindrical chamber and the outer surface of the elongated tubular means positioned below the piston rod. The pumping chamber communicates with the first working liquid chamber through the ejection valve and communicates with the fourth working liquid chamber within the second outer chamber through the liquid passage of the elongated tubular means and the suction valve.

In order to moderately damp the fluctuation of the suspension when passengers get off the vehicle or freights are taken therefrom whereby the applied load on the suspension is decreased, the following damping mechanism is employed in the conventional suspension.

This damping mechanism comprises a cylindrical sleeve slidably fitted over the outer circumferential surface of the elongated tubular means, an annular projection integrally formed at the lower end of the sleeve and an orifice formed in the elongated tubular means, wherein the upper end of the sleeve comes in contact with a step portion of the elongated tubular means and the lower end of the sleeve is biased by a helical compression spring disposed between the annular projection of the sleeve and the bottom portion of the cylinder.

In operation, a decreased load is applied to the upper surface of the suspension through the vehicle body, the balance between an internal pressure within the first working liquid chamber and the first outer chamber, and the vehicle load is broken. As a result, the suspension cylinder rapidly moves upwards relative to the piston. At this time, the elongated tubular means also moves in the direction of drawing from the piston.

At the same time, the sleeve fitted over the elongated tubular means is moved upwards together with the elongated tubular means by the expanding force of the helical compression spring.

In the process of this displacement, the annular projection of the sleeve is brought into engagement with the lower end of the piston head, thereby making the movement of the sleeve impossible. As a result, the elongated tubular means solely moves upwards. Therefore, the orifice which had been covered by the sleeve is now opened to connect the first working liquid chamber with the liquid passage within the elongated tubular means. As a result, the working liquid within the first working liquid is supplied to the fourth working liquid chamber through the liquid passage. Thereby, the level of the vehicle lowers until the inner pressure within the first working liquid chamber and the residual vehicle load are balanced thereby to reach the normal level.

Thus, the conventional suspension makes it possible to damp the fluctuation of the suspension or displacement between the suspension cylinder and the piston. However, because the complicated damping mechanism has been employed, various drawbacks are pointed out as follows:

(1) From a mechanical viewpoint, the number of parts cannot be reduced. Further, high accuracy in machining the outer radial dimension of the step portion of the elongated

tubular means or the inner radial dimension of the sleeve is required.

(2) The provision of the helical compression spring within the liquid chamber of the piston enlarges the volume thereof and lowers the pumping performance.

(3) It is required that the orifice has a diameter as large as being not to be blocked in the event that rubbish collects within the liquid passage. Accordingly, when the applied load on the suspension is decreased, the first working liquid chamber communicates with the fourth working liquid chamber through the orifice having a relatively large diameter. As a result, the pressure within the first liquid chamber is rapidly lowered. This means that it is difficult to moderately damp the suspension.

(4) When the vehicle is turning, there may occur an undesirable phenomina that, according to the centrifugal force, solely one side of the supraspring portion of the vehicle is lifted while the other side thereof lowers. In such a case, the pressure within the first working liquid chamber on the side of the lifted suspension is rapidly lowered.

With the above in mind, an object of the present invention is to provide a hydropneumatic suspension for an automotive vehicle including a novel damping structure which makes it possible moderately to damp the fluctuation of the suspension.

Another object of the present invention is to provide a hydropneumatic suspension for an automotive vehicle which makes it possible to simplify the structure thereof and reduce the number of parts thereof.

A further object of the present invention is to provide a hydropneumatic suspension for an automotive vehicle which makes it possible to prevent the sudden change of the working liquid within the working liquid chamber when the suspension is subject to the excessive displacement.

A still further object of the present invention is to provide a hydropneumatic suspension for an automotive vehicle which makes it possible to return the vehicle height to its predetermined level when the freight are taken from the vehicle or passengers alight from the vehicle.

According to the present invention, there is provided a hydropneumatic suspension for an automotive vehicle comprising a suspension cylinder comprising an outer tubular member and an inner tubular member, the space between the outer tubular member and the inner tubular member being partitioned into first and second outer chambers, a piston slidably fitted into the inner circumferential surface of the inner tubular member with a liquid-tight relationship, the piston consisting of a hollow cylindrical member extending in the axial direction of the inner tubular member, a cap member fitted over the cylinder so as to cover the upper end thereof, an elongated tubular means including a liquid passage, the upper end thereof being integrally connected to the cap and the lower end thereof extending in the axial direction of the piston, a first working liquid chamber defined by the inner circumferential surface of the inner tubular member, the upper surface of the piston, and the outer circumferential surface of the elongated tubular means, a second working liquid chamber defined by the inner circumferential surface of the inner tubular member, and the inner circumferential surface of the piston, a first cylindrical diaphragm disposed within the first outer chamber, the first diaphragm partitioning the first outer chamber into a first gas chamber and a third working liquid chamber, a second cylindrical diaphragm disposed within the second outer chamber, the second diaphragm partitioning the second outer chamber into a second gas chamber and a fourth working liquid chamber, a suction valve provided at the lower end of the elongated tubular means, an ejecting valve provided at the upper end of the piston, a pumping chamber formed within the piston, the pumping chamber communicating with the first working liquid chamber through the ejecting valve and communicating with the fourth liquid chamber within the second outer chamber through the suction valve and the liquid passage within the elongated tubular means and a first passage provided in the vicinity of the inner tubular member, the lower end thereof communicating with the fourth working liquid chamber while the upper end thereof communicating with the first working liquid chamber when the applied load on the suspension is decreased whereby the piston head is below the upper end of the first passage.

A hydropneumatic suspension for use with an automotive vehicle according to the present invention in which the inner tubular means is further provided with a second passage which connects the first working liquid chamber with the fourth working liquid chamber when the displacement between the suspension cylinder and the piston is large.

According to another embodiment of the present invention, there is provided a first passage consisting of a longitudinal groove formed in the outer circumferential surface of the inner tubular means, and an elongated cover member the upper end of which is integral with the inner tubular member, which is provided so as to cover the longitudinal groove.

A first modification of the first passage employed in the present invention is a capillary tube disposed on the outer circumferential surface of the inner tubular means.

A second modification of the first passage employed in the present invention is a hole one end of which communicates with the fourth working liquid chamber while the other

end of which communicates with the first working liquid chamber.

A third modification of the first passage employed in the present invention is a helical tube disposed along the outer circumferential surface of the inner tubular member.

A fourth modification of the first passage employed in the present invention comprises a circular groove helically disposed along the outer circumferential surface of the inner tubular means, and a cylindrical member fitted over the inner tubular means so as to cover the circular groove.

A fifth modification of the first passage employed in the present invention comprises a cylindrical member fitted over the outer circumferential surface of the inner tubular means, and a helical groove provided along the inner circumferential surface of the cylindrical member.

Embodiments of the present invention will now be described in greater detail with reference to the accompanying drawings of which:

Figure 1 is a cross sectional side elevation illustrating a conventional hydropneumatic suspension,

Figure 2 is a cross sectional side elevation illustrating a preferred embodiment of a hydropneumatic suspension according to the present invention,

Figure 3 is a cross sectional plan view taken along the line III-III of Fig. 2,

Figure 4 is a cross sectional side elevation illustrating a first preferred modification of a first passage shown in Fig. 2,

Figure 5 is a cross sectional side elevation illustrating a second preferred modification of a first passage shown in Fig.2,

Figure 6 is a cross sectional side elevation illustrating a preferred third modification of a first passage shown in Fig. 2,

Figure 7 is a perspective view illustrating the first passage shown in Fig. 6,

Figure 8 is a cross sectional plan view of the first passage shown in Fig. 7,

Figure 9 is a cross sectional side elevation illustrating a preferred fourth modification of a first passage shown in Fig. 2,

Figure 10 is a perspective view of the first passage shown in Fig. 9,

Figure 11 is a cross sectional side elevation illustrating a preferred fifth modification of a first passage shown in Fig. 2, and

Figure 12 is a perspective view of a first passage shown in Fig. 11.

In these drawings, the same reference numerals indicate the same or similar element of the hydropneumatic suspension for an automotive vehicle.

Before proceeding with the explanation of the embodiments of the present invention, one example of a conventional prior art hydropneumatic suspension will be described.

Referring to Fig. 1 illustrating a conventional prior hydropneumatic suspension, reference numeral 10 denotes a suspension cylinder having a bottom portion 12 in which there is formed with a central aperture 14. At the top of the suspension cylinder 10, there is provided a threaded portion 11 to which a cap member, which will be referred to later, is engaged. Reference numeral 16 denotes an inner cylinder comprising an outer cylindrical member 16A and an inner cylindrical member 16B. The outer cylindrical member 16A tightly contacts an annular shoulder 18 projected inwardly in a radial direction from the inner surface of the suspension cylinder 10.

Reference numeral 20 denotes a cap member screwed into the upper end of the suspension cylinder 10 and secured to the inner cylinder 16. In use, the cap member 20 is connected to a vehicle body or chassis (not shown). Reference numeral 22 denotes a piston consisting of a hollow cylindrical member. The piston 22 is provided with a piston head 23 slidably fitted into the inner cylindrical member 16B of the inner cylinder 16 in a liquid-tight manner. The hollow cylindrical member 22 is movable upwards and downwards guided by the aperture 14 in the bottom portion 12. Reference numeral 24 denotes an elongated tubular extension of the cap member 20 and has a liquid passage 25. The elongated tubular extension is, at the upper end thereof, integrally connected to the cap member 20, while at the lower end thereof extends in the axial direction within the piston 22 through an aperture in the piston head 23.

Reference numeral 15 denotes an attachment member part only of which is seen in Fig. 1 and by means of which the piston 22 is coupled directly or indirectly to a wheel axle or wheel shaft.

Reference numeral 26 denotes a sleeve slidably fitted over the outer circumferential surface of the elongated tubular extension 24. The upper end of the sleeve 26 is adapted to seat on a step portion 24*a* of the elongated tubular extension 24.

The sleeve 26 is further provided, at the lower portion thereof, with an annular projection 26*a*. Reference numeral 30 denotes a helical compression spring disposed between the annular projection 26*a* and the bottom surface of the inner cylindrical member 22.

Leakage passed the piston head 23 is prevented by an annular seal 36.

Thus, a first, working-liquid chamber 100 is defined by the inner circumferential surface of the inner tubular member 16B, the upper surface of the piston head 23, and the outer circumferential surface of the elongated tubular extension 24 positioned above the piston head 23.

A second, working-liquid chamber 110 is defined by the inner circumferential surface of the inner tubular member 16B, the lower surface of the piston head 23 and the outer

circumferential surface of the piston 22.

The space between the outer tubular member 16A and the suspension cylinder 10 is partitioned by the shoulder 18 into first and second outer chambers, designated generally by reference numerals 120 and 130, respectively.

A first cylindrical diaphragm 32 is disposed within the first outer chamber 120 between the cap 20 and the shoulder 18 and partitions chamber 120 into a first gas chamber 122 and a third, working-liquid chamber 124. A second cylindrical diaphragm 34 is disposed within the second outer chamber 130, between the shoulder 18 and the bottom portion 12 and partitions chamber 130 into a second gas chamber 132 and a fourth working liquid chamber 134.

The third working liquid chamber 124 is in communication with the first working liquid chamber via an aperture 100A in the upper part of the outer cylindrical member 16A.

The fourth working liquid chamber 134 communicates with passage 25 via apertures 134A in the lower part of the outer cylindrical member 16A and with the second chamber 110 via apertures 110A in the lower part of the inner cylindrical member 16B.

As is well known, the gas chambers are filled to a requisite pressure with a suitable inert gas while the liquid chambers are filled with a suitable hydraulic liquid.

Fig. 1 shows the position the parts occupy when no load is applied to the vehicle. A suspending stress is produced dependent on the gas pressure within the first gas chamber 122. In such a condition, the inner upper surface of the piston head 23 is in alignment with a step portion 24*a* of the elongated tubular member.

When the vehicle is loaded by passengers and/or freight, the suspension cylinder 10 moves downwardly relative to the piston 22 according to the increase in load.

At this time, the elongated tubular member 24 advances inwardly relative to the cylinder 10, so that an internal pressure of the first working-liquid chamber 100 increases resulting in an increase of the suspending reactive force.

In this condition, when the vehicle starts to move, vibration is caused by the movement of the vehicle. This vibration brings about a reciprocal movement of expansion and contraction between the suspension cylinder 10 and the piston 22.

At the expansion stroke, because of the vibration of the suspension, the working liquid in the pumping chamber 22*a* formed in the hollow cylindrical member 22 is decompressed somewhat. As a result, working liquid flows from the fourth working-liquid chamber 134 of the second outer chamber 130 through the liquid passage 25 and the one-way valve 38.

On the other hand, at the contraction stroke, the working liquid within the pumping chamber 22*a* is fed to the first working-liquid chamber 100 via passage 23*a* and controlled by a spring-loaded flap valve 40 located in a recess in the piston head 23. With the above successive pumping actions, the working liquid accumulates in the first working-liquid chamber 100 to elevate the inner pressure of the working liquid within the first working liquid chamber 100. As a result, the piston 22 is pushed outwardly, whereby the vehicle level gradually returns to its normal postion.

Thus, the upper surface of the piston 23 head moves slightly beyond the step portion 24*a* of the elongated tubular member 24. As a result, a passage 44 formed close to the step portion 24*a* is opened to connect the pumping chamber 22*a* with the first working-liquid chamber 100. Accordingly, the pumping action is now cancelled to maintain the normal level.

In this condition, if the loading of the vehicle is reduced, an imbalance occurs between the pressure within the first gas chamber 122, the first working liquid chamber 100, and the vehicle load. As a result, the suspension cylinder 10 is forced to rise up with respect to the piston 22.

At this time, the elongated tubular extension 24 also moves upwardly relative to the piston 22. At the same time, the sleeve 26 fitted over the elongated tubular extension 24 follows the movement due to the compression force of the helical compression spring 30. During the time of this movement, the annular projection 26*a* of the sleeve 26 is maintained in contact with the inner lower end of piston head 23, so that the movement of the sleeve 26 is limited. As a result, the elongated tubular extension 24 opens an orifice 42 which had previously been closed by the sleeve 26, thereby connecting the first working-liquid chamber 100 with the liquid passage 25. Accordingly, the working liquid within the first working-liquid chamber 100 flows into the fourth working liquid chamber 134 through the liquid passage 25. Thus, the level of the vehicle drops until the pressure within the first working-liquid chamber 100 and the vehicle load are balanced.

Although the conventional suspension permits damping of the fluctuations of the suspension or displacement between the suspension cylinder 10 and the piston 22, it has been difficult or impossible to avoid the various drawbacks stated above because of the complicated damping mechanism.

The preferred embodiments of a hydropneumatic suspension for an automotive vehicle will now be described with reference to the drawings.

Figs. 2 and 3 show a first embodiment of the present invention, which is similar to Fig. 1 assembly except for a novel damping struc-

ture. Reference numeral 50 denotes a first passage comprising a longitudinal groove 54 formed in the outer circumferential surface of the inner tubular member 16, and an elongated cover member 52 provided outside the outer circumferential surface of the inner tubular member 16. The elongated cover member 52 is provided at the upper end thereof integrally with the outer circumferential surface of the inner tubular member 16.

The first passage 50 is thus constituted so as to increase the resistance to fluid flow.

The lower end of the first passage 50 communicates with the fourth working-liquid chamber 134, while the upper end thereof, when uncovered, communicates with the first working-liquid chamber 100.

When the applied load on the upper surface of the suspension is decreased, imbalance between an internal pressure within the first working-liquid chamber 100, the first outer chamber 120, and the vehicle load occurs. As a result, the suspension cylinder 10 moves upwards rapidly relative to the piston 22. When the piston head 23 is below the upper end of the first passage 50, the first working-liquid chamber 100 communicates with the fourth working-liquid chamber 134. Thereby, the level of the vehicle drops until the pressure within the first working liquid chamber 100 and the residual vehicle load balance to reach the normal level. This damping effect is in particular available when this damping mechanism comprising the first passage is used in order to lessen the difference being between the left and right side of the vehicle when the vehicle turns.

Thus, the suspension according to the first embodiment of the present invention makes it possible to damp moderately the fluctuations of the suspension with a simple damping structure as compared to the conventional one.

It is to be noted that it is possible to construct the first passage 50 with a width greater than the diameter of the orifice 42 required in the prior art. Accordingly, there is little possibility that the first passage 50 will become obstructed.

Thus, the provision of the first passage 50 makes it possible to connect the first working-liquid chamber with the fourth-working liquid chamber to damp moderately fluctuations of the suspension.

As understood from the damping operation by the first passage, when the load on the vehicle is reduced, the level of the vehicle drops to balance the internal pressure within the first working liquid chamber with the residual vehicle load. However, there is a possibility that it takes a relatively long time to establish the balance because of resistance offered to liquid flowing through the first passage 50.

With the above in view, in order to shorten the balancing time, the damping mechanism according to the present invention may further comprise a second passage 60 consisting of a hole provided through the inner tubular member 16.

The second passage 60 connects the second working-liquid chamber 100 with the fourth-working liquid chamber when the piston head is below the second passage. It is to be noted that the position of the second passage is so selected that the first working-liquid chamber 100 communicates with the fourth working-liquid chamber 134 through the second passage 60 when the displacement between the suspension cylinder 10 and the piston 20 is very large. Thus, the suspension with this modification shortens the balancing time.

Reference is now made to the detail of the damping action employed in the present invention.

When the displacement between the suspension cylinder and the piston is very large, that is, at the initial displacement state, the liquid within the first working-liquid chamber 100 communicates with the fourth working-liquid chamber 134 mainly through the second passage 60 having a relatively small fluid resistance. At this time, there is a small amount of liquid flowing through the first passage because of its large resistance to flow.

Then, the displacement between the suspension cylinder and the piston becomes small and the second passage 60 is closed by the piston head 23. Accordingly, the residual displacement between the suspension cylinder 10 and the piston 22 is gradually decreased since the liquid within the first working-liquid chamber 100 is transferred into the fourth-working liquid chamber 134 solely via the first passage 50.

Thus, the damping action makes it possible to damp moderately the displacement between the suspension cylinder and the piston by the co-operative action of the first and second passages.

Referring now to Fig. 4, there is shown a first modification of the first passage comprising a capillary tube 150 disposed along the outer circumferential surface of the inner tubular member 16. The upper end of the capillary tube 150 communicates in certain positions of the piston head 23, with the first working-liquid chamber 100 while the lower end thereof communicates with the fourth-working liquid chamber 134.

Referring now to Fig. 5, there is shown a second modification of the first passage consisting of a hole 250 provided through the inner tubular member 16B.

It is here noted that the first working-liquid chamber 100 communicates with the liquid passage 25 via a passage 48 in which a one-way valve 46 is assembled.

Referring now to Figs. 6 to 8, there is shown a third modification of the first passage, generally designated by reference numeral 350, comprising a hole 352 provided through the inner tubular member 16, and a tube 354 helically coiled round the outer circumferential surface of the inner tubular member 16B. The upper end of the tube 354 communicates with the hole 352 while the lower end thereof communicates with the fourth working-liquid chamber 132.

Referring now to Figs. 9 and 10, there is shown a third modification of the first passage, generally designated by reference numeral 450, comprising a circular groove 456 helically disposed along the outer circumferential surface of the inner tubular member 16B, and a cylindrical sleeve 454 fixed over the outer circumferential surface of the inner tubular member 16.

Referring now to Figs. 11 and 12, there is shown a fourth modification of the first passage, generally designated by reference numeral 550 comprising a hole 552 formed through the inner tubular member 16B the inner end of which communicates with the first working-liquid chamber 100 when the piston head is below the inner end of the hole 552, and with a helical groove 556 provided along the inner circumferential surface of a cylindrical member 554 the upper end of which communicates with the outer end of the hole 552 and the lower end of which communicates with the fourth working liquid chamber 134.

As is clear from the foregoing description, the following advantages will accrue with the hydropneumatic suspension according to the present invention:

(1) In comparison with the conventional suspension in which a mechanical damping mechanism is employed, the hydropneumatic suspension of the invention is quite simple in structure. That is, a sleeve for which highly-accurate machining is required and the helical coil spring for biasing the sleeve are eliminated, thereby makes it possible to facilitate machining and reduce the number of parts.

(2) The suspension according to the present invention is provided with a first passage provided in the vicinity of the outer circumferential surface of the inner tubular member, one end of the first passage communicating with the first working-liquid chamber and the other end thereof communicating with the fourth-working liquid chamber. Accordingly, in the event that the first passage has a diameter sufficiently large so that same cannot become blocked, the suspension makes it possible to prevent the pressure within the first working-liquid chamber from being rapidly lowered when the load applied to the suspension abruptly decreases. Thereby, a reduction in the difference in level between the left and right side of the vehicle after the vehicle turns is made possible.

The suspension further comprises a second passage consisting of a hole provided through the inner tubular member. With the second passage, when the load on the vehicle reduces, it is possible to shorten the time it takes for the vehicle to return to its prescribed height.

(3) The suspension does not include a spring within a liquid chamber defined by the inner surface of the piston, the lower surface of the piston head, and the outer surface of the elongated tubular means. Accordingly, to achieve the same pumping ability, it is possible to reduce the volume of the liquid chamber by the volume occupied by the spring, thereby obtaining a smaller-sized suspension.

Furthermore, the suspension makes it possible to enlarge the thickness of the hollow cylindrical member constituting the piston by a space occupied by the piston, thereby increasing the rigidity of the piston.

While the present invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit and scope of invention.

CLAIMS

1. A hydropneumatic suspension for an automotive vehicle comprising:

(a) a suspension cylinder comprising an outer tubular member and an inner tubular member, the space between said outer tubular member and said inner tubular member being partitioned into first and second outer chambers,

(b) a piston having a piston head slidably fitted into the inner circumferential surface of said inner tubular member with a liquid-tight relationship, said piston consisting of a hollow cylindrical member extending in the axial direction of said inner tubular member,

(c) a cap member fitted over the cylinder so as to cover the upper end thereof,

(d) an elongated tubular means including a liquid passage provided through the piston head, the upper end thereof being integrally connected to said cap and the lower end thereof extending in the axial direction of said piston,

(e) a first working liquid chamber defined by the inner circumferential surface of said inner tubular member, the upper surface of said piston head, the outer circumferential surface of said elongated tubular means and the lower surface of said cap member,

(f) a second working liquid chamber defined by the inner circumferential surface of said inner tubular member, the lower surface of said piston head, and the outer circumferential surface of said piston,

(g) a first cylindrical diaphragm disposed

within said first outer chamber, said first diaphragm partitioning said first outer chamber into a first gas chamber and a third working liquid chamber,

(h) a second cylindrical diaphragm disposed within said second outer chamber, said second diaphragm partitioning said second outer chamber into a second gas chamber and a fourth working liquid chamber,

(i) a suction valve provided at the lower end of said elongated tubular means, said suction valve communicating with said liquid passage,

(j) an ejecting valve provided within said piston head,

(k) a liquid chamber defined by the inner circumferential surface of said piston, said liquid chamber communicating with said working liquid chamber through the suction valve and communicating with said second outer chamber through said liquid passage of said elongated tubular means and said ejecting valve,

the improvement comprising: a first passage provided in the vicinity of said inner tubular member, the lower end thereof communicating with said fourth working liquid chamber while the upper end thereof communicating with said first working liquid chamber when said piston head is below the upper end of said first passage.

2. A hydropneumatic suspension for an automotive vehicle as defined in claim 1, wherein said inner tubular member is provided with a second passage communicating said second working liquid chamber with said fourth working liquid chamber when said piston head is below said second passage.

3. A hydropneumatic suspension for an automotive vehicle as defined in claim 1, wherein said first passage is a capillary tube disposed along the outer circumferential surface of said inner tubular member.

4. A hydropneumatic suspension for an automotive vehicle as defined in claim 1, wherein said first passage is a helical tube disposed along the outer circumferential surface of the inner tubular means.

5. A hydropneumatic suspension for an automotive vehicle as defined in claim 1, wherein said first passage comprises a hole one end of which communicates with said fourth working liquid chamber and the other end of which communicates with said first working liquid chamber when the piston head is below the other end of the hole.

6. A hydropneumatic suspension for an automotive vehicle as defined in claim 1, wherein said first passage comprises a hole formed through said inner tubular member the inner end of which communicates with the first working liquid chamber when the piston head is below the inner end of said hole, a cylindrical member fitted over the outer circumferential surface of said inner tubular member and a helical groove provided along the outer circumferential surface of the inner tubular member the upper end of which communicates with the outer end of said hole and the lower end of which communicates with said fourth working liquid chamber.

7. A hydropneumatic suspension substantially as herein described with reference to and as illustrated by Figs. 2 and 3 of the accompanying drawings.

8. A hydropneumatic suspension substantially as herein described with reference to and as illustrated by Fig. 4 of the accompanying drawings.

9. A hydropneumatic suspension substantially as herein described with reference to and as illustrated by Fig. 5 of the accompanying drawings.

10. A hydropneumatic suspension substantially as herein described with reference to and as illustrated by Figs. 6, 7 and 8 of the accompanying drawings.

11. A hydropneumatic suspension substantially as herein described with reference to and as illustrated by Figs. 9 and 10 of the accompanying drawings.

12. A hydropneumatic suspension substantially as herein described with reference to and as illustrated by Figs. 11 and 12.

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